4.—Drought effects in the Gibson Desert

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Abstract

On a recent expedition through part of the Gibson Desert and adjacent areas it was observed that most of the vegetation had been severely affected by drought during some recent period, with widespread death and dieback. Regeneration had since taken place. Brief details of the principal vegetation types and of the effects of drought are given. The latter are shown not to have been caused by fire and are traced to three years of drought in 1961-4. It is suggested that infrequent severe droughts cause cyclic death and regeneration of vegetation in these arid areas, producing more or less even-aged stands.

Introduction

In September-October 1966 a party consisting of the writer and Mr A. S. George, a botanist on the staff of the West Australian Department of Agriculture, travelled across the southern part of the Gibson Desert and through the mountainous area of the Warburton, Rawlinson and adjoining ranges (the Warburton Natural Region of Clarke, 1927) subsequently crossing the Great Victoria Desert in a southerly direction. This whole region, lying between the 123rd meridian and the State boundary at the 129th meridian, and south of the 24th parallel, was until recently one of the most inaccessible parts of Australia, but between 1956 and 1963 was opened up by numerous graded tracks constructed by the Commonwealth Government for survey purposes (Beadell, 1965). These tracks were used by our party for observations of flora and vegetation and it was soon noticed that much of the plant cover was in process of regeneration after a period of severe drought which must have occurred in recent years. Particular note was therefore taken of drought effects, and on return rainfall records were obtained for a climatic anaylsis, forming the subject of this paper.

General description of the region

The most varied and scenically interesting country occurs in the east of the region where mountainous country typical of Central Australia crosses the State boundary for some distance. In latitude 25° the Petermann Ranges and their continuation as the Schwerin Mural Crescent and Rawlinson Range extend westward for 90 miles, with a group of minor ranges to the north of them. These are low mountains of massive quartzite with flat, sandy plains between them, usually with dunes. Further south, in latitude 26° another chain of small isolated mountains of gneiss much intruded with basalt and basic dykes extends 150 miles westward from the State boundary to end at the Warburton Range. The country adjoining these ranges consists mainly of plains of heavy soil under mulga, though sandy areas do occur.

To the west and south of this massif of ancient rocks the country is underlain by more or less horizontal sediments of Permian and later ages, predominantly sandstones, and is of relatively low relief. Broad, level plateaux are dissected by shallow valleys often bordered with low breakaways. Immediately to the west of the mountain range complex this plateaux country consists predominantly of very extensive surfaces of ironstone gravel with limited sandy valleys in which dunes are developed. This area constitutes the Gibson Desert and in the region studied (south of the 24th parallel) it occupies a triangle whose sides bear 20° and 315° respectively from an apex at lat. 27° 30′ S, long. 126° E. Laterite plains, with a characteristic vegetation, are confined within this triangle. Outside it, the country is predominantly sandy with belts of dunes interspersed with heavier soil flats. Further to the southwest, sand plains without dunes are encountered. The sandy country outside the triangle may be said to constitute the Great Victoria Desert. The most conspicuous effects of drought were observed in the Gibson Desert and mountain area and diminished south of the 27th parallel.

Human settlement in this region consists of the United Aborigines Mission at the Warburton Range, established in 1935 and the Giles Weather Station established in 1956. The mission now has a population of some 300 natives. Most of the mountain area is an Aboriginal Reserve but it seems that in recent years the native population has become concentrated at the mission so that there are no longer any people living and hunting in the wild further out. The population of Europeans is a handful at either settlement. There are no sheep or cattle on the country anywhere and kangaroos and emus appear to be very sparse. Fresh camel tracks were frequently seen by us, but no actual animals. No trace of rabbits was observed.

Meteorological observations have been recorded at the mission since 1940 and at Giles since 1956. These will be discussed later. The annual average rainfall in both cases has been 8½ inches.

Vegetation

The principal vegetation types are (1) scrub heath on sand dunes, (2) tree and shrub steppe on sand plains, ((3) mulga scrub on red loam soils and on rock and (4) so-called "mulga

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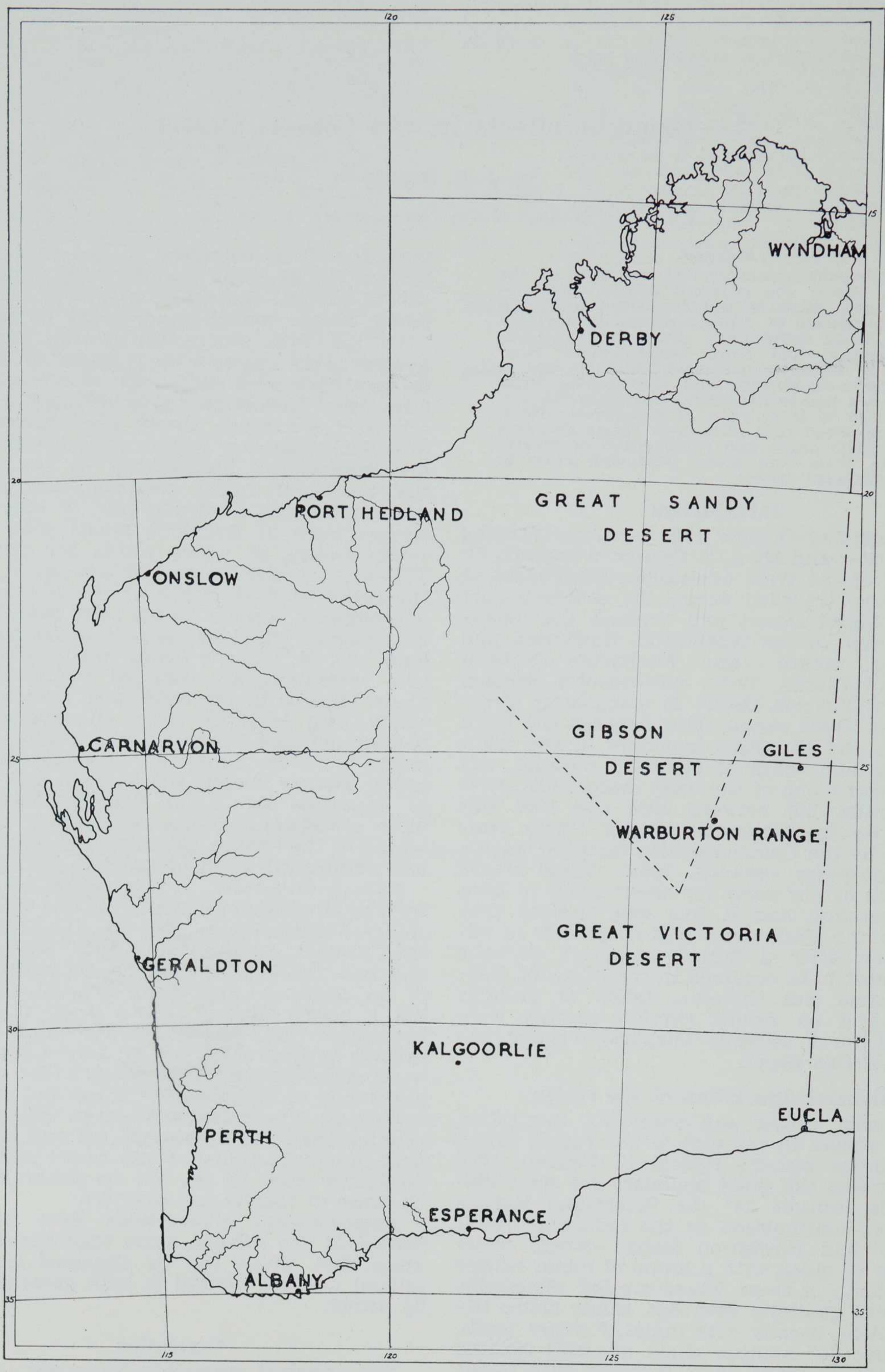

Figure 1.—Map of the area studied, showing localities mentioned in the text.

parkland" on laterite plains. Minor communities which are outside the scope of the present paper include mallee which in this region is confined to kunkar soils in depressions and near salt lakes, only accounting for small areas; a range of salt-tolerant communities in lake beds, and low wattle scrub on the mountain ranges.

1. Sand dunes

The vegetation of sand dunes is very consistent throughout the region and differs markedly from that of dunes in the Great Sandy Desert further north which is a spinifex or steppe formation with *Plectrachne schinzii* dominant, and scattered shrubs and trees. Here in the south both *Plectrachne* and *Triodia* do occur, but sparingly, dominance being assumed by the low ericoid shrub *Thryptomene maisonneuvii* which frequently forms an almost continuous cover especially on the lower flanks of the dunes. It is rather more sparse on their crests. Taller species of shrubs up to 6 ft. tall occur widely spaced, and are at their most frequent along the crests and upper flanks of the dunes. In this class *Grevillea stenobotrya* and *Acacia salicina* are most consistent components. Others include *Grevillea pterosperma, Gyrostemon ramulosus,* various species of *Eremophila,* an *Anthotroche* and *Crotalaria cunninghamii.* Other low shrubs include *Micromyrtus flaviflora.* Rather rarely there appear along the crests of the dunes odd trees of the desert bloodwood *(Eucalyptus sp. aff. cliftoniana),* a species which is here at the limit of its range, being much more common in the Great Sandy Desert. It was not observed at all south of the 27th Parallel.

With only these few trees and a few scattered plants of spinifex this is essentially a shrub community which in both physiognomy and floristic composition is related to the scrub heaths of the Southwestern Province which in the same way feature a low, more or less continuous stratum of ericoid shrubs belonging mainly to the Myrtaceae with an open upper stratum mainly of Proteaceae with some Acacia.

Where sandhills are close together, the dune scrub is continuous. Where they are widely spaced other vegetation occurs between them and is usually either mulga or tree/shrub steppe according to soil.

2. Sand plains

It is perhaps curious that the vegetation of flat sandy areas is entirely different from that of sand dunes. Invariably in this region sand plains carry hummock grassland, or steppe in the sense of Gardner (1942) and Beard (1966). *Triodia basedowii* is the almost universal constituent, together with a tree or shrub component which varies locally. The Great Victoria Desert is characterised by the mallee *Eucalyptus pyriformis* and the tree *Eucalyptus gongylocarpa* which frequently associate but perhaps as frequently occupy separate areas. In the southern part of the Great Victoria Desert open, park-like stands of *E. gongylocarpa* with a spinifex floor are common and form an attractive landscape but devoid of any other conspicuous plant species. Shrub steppe of *E. pyriformis* on the other hand generally has numerous associated shrubs including *Hakea microneura, H. lorea, Grevillea juncifolia, Acacia salicina, A. helmsii, Melaleuca spp.* and *Wehlia thryptomenoides.* Within the Great Victoria Desert the two eucalypts tend to invade the sandhills, of which the vegetation becomes more mixed.

In the general area of the Rawlinson Range complex there is a widespread occurrence of tree steppe formed by the desert oak, *Casuarina decaisneana,* over a spinifex floor of *Triodia basedowii.* The Casuarina trees grow to 40 ft. tall and form open stands of pleasing appearance. There are no conspicuous associated species.

A minor shrub steppe community found on sand in the Gibson Desert is one of *Grevillea juncifolio, G. eriostachya, Hakea lorea, Acacia linophylla, Eremophila leucophylla,* and frequently *Eucalyptus gamophylla* (a mallee) over *Triodia basedowii*

3. Mulga

The mulga formation is an open community of large shrubs mostly about 10 ft. tall but reaching twice this height or more in favourable situations with adoption of a tree habit (i.e. a definite trunk instead of branching from the base). *Acacia aneura* is the sole species in this layer. In a pure mulga formation on heavy loam flats there may be sparse undershrubs of *Eremophila spp.* and *Ptilotus obovatus* but the soil is normally quite bare except for ephemerals in season—annual grasses and composites. Where the soil becomes more sandy, *Triodia basedowii* comes in and occupies the ground to some extent. On rocky ground such as along the tops of breakaways a stunted mulga is found.

Through this whole region mulga is typically to be found along lines of breakaways, on top and at the foot, and forms patches between dunes in sandhill areas. It will also occupy plains of red loam soil in sand-free areas, particularly in the vicinity of the hill ranges in the Warburton-Giles sector, and is an important component of the mosaic on laterite plains as will be shown in the next paragraph.

4. "Mulga parkland"

The extensive rolling laterite plains of the Gibson Desert are vegetated with a mosaic of intergrading communities of mulga, shrub steppe and grass steppe which as a whole may be conveniently regarded as an attenuated mulga formation and termed the mulga parkland. Patches of typical dense mulga scrub occupy substantial portions of the laterite plains, generally in dips, depressions or drainage lines but at times with no obvious topographic control. Such patches, which have a bare floor, grade outwards into mulga with a spinifex floor and this in turn opens out with the mulga becoming sparser, and associated with other species. At this stage there is a recognisable shrub steppe association, which may be called the *Hakea-Acacia* shrub steppe. Characteristic species are *Hakea lorea, Acacia pruinocarpa* and *Acacia aneura* which are all very consistent, and, rather more sporadically, the mallee *Eucalyptus kingsmillii, Acacia grasbyi* and *Eremophila leucophylla.* In the poorest and stoniest parts the

Figure 2.—Effect of drought on sandhill vegetation. Gunbarrel Highway west of the Rawlinson Range.

shrub steppe opens out still further tending almost to a pure grass steppe of spinifex hummocks alone. On such sites the visible ground is surfaced with a desert pavement or *hamada* of rounded pieces or ironstone up to 2 inches in diameter (Fig. 8). Underlying "soil" (if that term is applicable) consists of about 6 inches of loose friable ironstone gravel overlying a massive indurated layer. In the direction of dense stands of mulga the top soil contains a higher proportion of loam with the ironstone component contracting to small nodules.

General note

It will be observed that this desert area is vegetated with plant formations which extend elsewhere and are already known in other parts of Australia. The inaccessibility and resulting ignorance of this region hitherto have led to a number of misconceptions becoming current, as is evident for example from Hall et all (1964), who state, apropos of a study of the Koonamore Vegetation Reserve in South Australia, situated in a mulga belt: "The 10 most common tree and shrub species found on Koonamore Vegetation Reserve are widely distributed across Australia, especially in an East-west direction . . . the Nullabor Plain and the Great Victoria, Gibson and Simpson Deserts are too arid for the survival of these species. The odd plant found within these areas has always been noted near a water source." This observation shows both the inadvisability of relying on herbarium records for distribution and the need for botanical collectors to record more ecological data. Two of the commonest species at Koonamore, *Acacia aneura* and *Casuarina cristata* occur throughout the Nullabor Plain, Great Victoria and Gibson Deserts wherever the particular soil type with which these species are associated occurs. In terms of rainfall and vegetation the Great Victoria and Gibson "Deserts" are not more arid than other parts of the interior adjacent to them. Their reputation as deserts appears to derive partly from the abundance of sandhill tracts and partly the want of surface water supplies, and both of these features are directly due to the geological structure of the country as a lowlying sedimentary basin.

Drought effects

Some of the more severe observed effects of drought are illustrated photographically in Figures 2-9. Figure 2 shows a sandhill with 2 desert bloodwoods against the skyline, both of which have died back very substantially and are now making weak epicormic growth. The slopes of the sandhill were clothed with bushes of *Thryptomene maisonneuvii* most of which have died, and with clumps of spinifex which

Figure 3.—Sandhill area severely affected by drought. On Sandy Blight Junction Road near Lake Hopkins.

Figure 4.—Desert oak grove partially killed by drought. Same area as Figure 3.

have fared rather better and come back into full vigour. Regeneration on the dune includes many pioneer subshrubs such as *Dicrastyles*.

Figure 3 is taken from the top of a sandhill in a particularly drought-stricken area near Lake Hopkins. The Walter James Range is visible at upper right, and the flat at lower right carries large desert oaks nearly all of which have died (see also Fig. 4). On the sandhill itself almost every plant died. Shrubs in the foreground are dead or almost so, and in the distance a few dead desert bloodwoods can be seen. Little or no regeneration had taken place here.

Figure 4 was taken only a few yards from Figure 3 and shows the desert oak grove in the flat, most of the trees dead and with their bark dropping off. Some in the rear have survived. Presumably no drought of this severity had occurred within the lifetime of these trees. The spinifex here had survived well though badly damaged, and at the time of the visit there was a good crop of yellow daisies which show up (*Helipterum stipitatum*).

Figure 5 shows a severe case of destruction of mulga, where a whole stand has perished leaving only bare earth with a few sparse clumps of annual grass. Such cases are fortunately rare, the more usual effect being as in Figure 6 where some only of the mulga bushes have died. In Figure 7 there had been copious regeneration of mulga already man-high.

Figure 8 shows the surface of a laterite plain of the Gibson Desert strewn with ironstone fragments. Former large spinifex clumps at lower left and upper right have died and partly rotted away, while small spinfex seedlings can be seen in process of replacing them. There is one just to the right of the centre of the photograph. It is interesting to note accumulation of small buckshot sized ironstone pebbles on the site of the old spinifex clumps, presumably due to sorting by wind.

Figure 9 shows an area of grass steppe in the Gibson desert where spinifex died or largely died back. Most of the spinifex visible is dead but some clumps have made regrowth. Regeneration in this case has been in the form of a lush growth of pioneer subshrubs and forbs, flowering when the photograph was taken. These included *Dicrastyles exsuccosa, Burtonia polyzyga, Halgania solanacea, Goodenia azurea, Trachymene glaucifolia* and three species of *Ptilotus*. It is interesting to note that a similar succession is observed in pastoral country in north-western Australia following deliberate burning of the spinifex for purposes of range management. Rapid seedling regeneration of *Triodia* is accompanied by a luxuriant crop of annuals, perennial forbs and subshrubs such as many species of *Ptilotus, Clianthus formosus, Goodenia stapfiana, Trachymene glaucifolia* and *Keraudrenia integrifolia*. The latter grow and flower luxuriantly for several

Figure 5.—Dead mulga. Gunbarrel Highway near the Todd Range.

Figure 6.—Mulga partly affected by drought. Gunbarrel Highway west of the Barker Range.

seasons, given adequate rains, but gradually recede as the spinifex becomes more fully established, eventually becoming rare and inconspicuous in a matured spinifex community.

Naturally the question arose as to whether the observed effects of death and regeneration resulted from fire and not drought, but this was easily decided by inspection of remaining dead material. Spinifex which is burned is completely consumed whereas remains of dead clumps were everywhere visible, some re-sprouting. Little if any of the dead woody plants in affected areas that were examined exhibited any signs of charring. This is not to say that fire does not occur in this type of country. No sign of any recent burn was seen anywhere during the whole trip of our party and the mission superintendent stated that bushfires did not occur in that country. Nonetheless signs of charring on old dead trees, stumps and logs could very frequently be seen. In the records of all the 19th century explorers, e.g. Lindsay 1893, it will be found that smoke from native fires was seen every day, and not of camp fires but of vegetation lit up for signals or hunting purposes. On approaching Queen Victoria Spring Lindsay recorded that most of the country had been burnt off and in one area an extremely severe fire had occurred about 2 years before.

Since the aborigines have become concentrated at the mission it appears that firing of the country has abated, so that in time some interesting vgetational changes may result.

The photographs reproduced were naturally taken of the most obvious and severe cases of drought effects which were patchy in their incidence. The photographs are therefore not typical of the region as a whole, the general average being much less severely affected, with many patches undamaged. This is to be expected; rain, especially when shed from thunderstorms, falls irregularly and soils vary in their moisture-holding capacity. Almost everywhere, however, at least some degree of damage was noticeable in death and dieback of plants.

Climatic data

Meteorological data have been recorded at the Warburton Range Mission since December 1940 and at the Giles Weather Station since September 1956. The figures were kindly made available to the writer by the Commonwealth Bureau of Meteorology. Records are continuously available for Giles, but four months' records—September to December 1940—are missing at the Warburton Range. Only the Warburton figures are used here for the climate

TABLE 1

Monthly Rainfall records at Warburton Range mission

Rainfall in hundredths of an inch

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1941	0	182	330	92	43	54	31	7	2	61	112	118	1032
1942	697	272	710	41	143	242	12	20	1	12	328	241	2719
1943	6	82	112	333	50	0	0	0	6	27	28	11	655
1944	7	0	4	303	4	10	14	115	17	17	59	140	690
1945	63	18	389	0	28	99	114	42	56	39	20	13	881
1946	12	480	125	4	19	48	6	0		no records			
1947	81	42	76	3	0	109	38	185	34	188	180	375	1311
1948	6	21	6	435	12	0	16	0	0	3	47	67	613
1949	1	202	15	0	276	10	1	3	7	0	106	45	666
1950	49	274	0	0	357	82	23	1	7	169	106	61	1129
1951	104	69	9	16	0	140	1	0	95	0	95	10	539
1952	189	7	34	24	251	12	54	49	16	165	142	35	978
1953	100	15	0	86	98	8	6	58	0	95	5	157	628
1954	22	0	0	274	112	25	10	4	0	102	0	63	612
1955	36	14	140	137	27	388	211	228	0	0	146	0	1327
1956	3	0	12	3	134	124	190	25	0	3	77	11	582
1957	38	144	13	0	16	98	36	14	12	17	0	239	627
1958	22	0	266	0	63	60	114	284	8	1	22	152	992
1959	37	27	0	73	0	39	99	0	3	0	4	107	389
1960	190	587	1	120	93	23	6	7	18	2	0	315	1362
1961	4	35	0	84	0	2	0	0	8	4	0	0	137
1962	39	52	22	57	64	0	68	13	0	150	8	19	492
1963	94	29	41	0	66	86	3	2	0	14	10	86	431
1964	32	0	0	199	73	17	0	389	60	0	105	193	1050
1965	0	0	80	0	28	20	55	0	0	7	144	60	394
1966	31	300	7	200	66	144	0	27	0	48	103	24	950
25 year average	74	95	91	99	80	72	44	59	14	45	78	102	853
No. of months receiving 0	2	6	6	7	4	3	4	6	9	5	5	2	59
No. of months receiving <.10 in.	8	7	11	9	5	7	10	12	17	11	9	3	110
Highest recorded	697	587	710	435	357	388	211	389	95	188	328	375	2719
No. of months receiving > 1.00 in.	5	8	7	8	6	6	5	5	0	4	9	10	73

analysis as they cover a longer period. Since 1956 the Giles figures have been closely comparable each month.

Considering first the monthly and yearly rainfall totals, given for the Warburton Range in Table 1, it will be seen that over the 25 years of records the annual rainfall has varied between 27.19 and 1.37 inches, averaging 8.53 inches. In an arid region of this kind average figures are not of great value, since it is critical extremes which are significant for vegetation. However, some discussion of both is desirable. Average monthly distribution, given at the foot of Table 1 as the "25-year average", appears to show a bias towards summer and early winter rainfall, with a relatively dry spring, September being a generally dry month. On the other hand the next line at the foot of the table shows that nil rainfall may be recorded in any month of the year with no conspicuous monthly bias except towards September. The next line again, for "negligible rains" of under 0.10 inches, shows rather more seasonal variation with a high figure for March—perhaps an intermission between summer and winter rains—and a high group in spring. Below this, an extraction of the highest monthly total on record shows little seasonal variation except a September-October drop. The last line gives the number of months in which appreciable rainfall of 1.00 inch or over has been recorded. The spring drop is again apparent. Such rainfall was received in 73 months out of the 300 in the 25-year period of records, or approximately 1 month in 4.

It is apparent from the monthly summaries that rainfall here is extremely erratic and unreliable with little seasonal pattern.

According to residents at the Warburton Range Mission, the 3 most recent seasons 1966, 1965 and 1964 had all been good years locally, whereas at least 3 years prior to that had been drought years. This is consistent both with field observation of a recent regeneration period of several years' duration, and with the monthly rainfall records. During the initial 18 years of records up to and including 1958 the lowest annual rainfall total was 5.39 inches. 1959 was a dry year with only 3.89 inches but was followed by a wet year with 13.62 inches. 1960 was the driest year on record with only 1.37 inches and was followed by 2 more dry years with totals of 4.92 and 4.31 inches in which rain was only light. The drought was not broken until April 1964.

More detailed evidence is obtainable from the daily rainfall records, computed in the form of "rain events" rather than the daily rainfall totals. Daily rainfall at 9 a.m. may be misleading as to effectiveness of precipitation. If rain is in progress at the time of measurement, a single fall may be split between two days. Conversely it will be readily understood that an isolated fall of .50 inch is not likely to be very effective in this arid region, whereas .50 inch received daily for five days is very likely to be effective and therefore is best recorded as a single "event" of 2.50 inches A rain event is defined as precipitation received on two or more consecutive days.

If the 20 years of records from January 1941 to December 1960, complete except for 4 months of 1946, are examined for evidence of an average pattern prior to the drought, 445 rain events of any magnitude (> .01 inch) were recorded, averaging 23 per year, the interval between them varying from 1 to 98 days, with a mean of 14.5 days. Most of these events were however weak and doubtfully effective. The question of rainfall effectiveness in the interior has been discussed by Slatyer (1962) for the Alice Springs area and Arnold (1963) for the Meekatharra-Wiluna area in Western Australia. The latter found that the rainfall sufficient to initiate plant growth varied from as little as 0.24 inch in July to 1.18 inches in December. It seems unnecessary in the present case to make the elaborate calculations embodying evaporation data which were employed by Arnold, especially as evaporation has not been recorded at the Warburton Range meteorological station. Effective rain events have been estimated instead on the basis of notes made by the observer there on growth of grass and wildflowers, and generally a figure of .80 inch is taken as the threshold. Events between .25 inch and this level are listed as minor effective rains with this result:—

	Total No. of events	Mean No. of Events per year	per cent total rainfall
20—year period 1941–1960			
—ineffective rain events <.25 inch		14.7	15
—minor effective rains		4.2	21
—major effective rains> ±.80 inch		3.3	64
		22.2	100
Drought period Jan. 1961—April 1964 (40 months)			
—ineffective rain events <.25 inch	46	13.8	43
—minor effective rains	14	4.2	47
—major effective rains> ±.80 inch	1	.03	10
	61	18.3	100

Figure 7.—Dense regeneration of mulga after drought, 10 miles north of Warburton Range Mission.

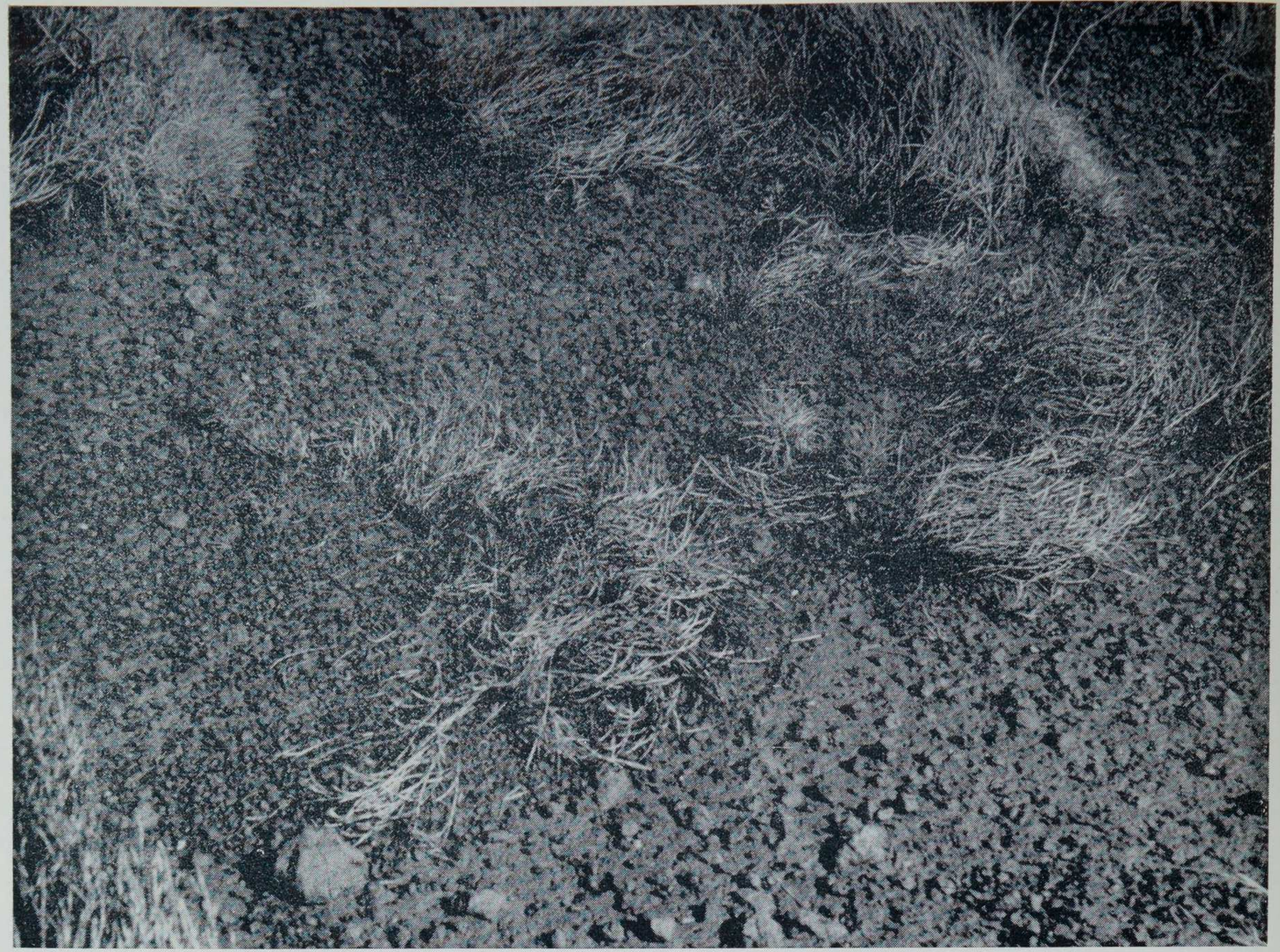

Figure 8.—Surface of laterite plain of the Gibson Desert showing hamada surface and regenerating spinifex seedlings among dead clumps.

It will be readily seen that in a "normal" period the vegetation is maintained by the occasional heavy soaking rains which may be expected about every four months on the average and account for two-thirds of all the precipitation. In practice, between 1941 and 1960 the interval between such falls varied from 3 to 376 days: it 4 times exceeded 300 days and 8 times 200 days. Droughts of up to a year are therefore common and are tolerated by the plant cover. During the severe drought period, the number and frequency of light ineffective rains remained more or less constant, but the heavy soaking rains virtually ceased. The drought began after three intermittent rain events totalling 2.79 inches during the week 14-21 December 1960. A rain event of 1.15 inches occurred over the four days 15-18 October 1862, 22 months later. In the meantime there had been five events between .30 and .40 inch, and three respectively .47, .53 and .57 inch, all dubiously effective. Heavy soaking rain did not recur until 28th April 1964, a further 18 months during which only light rain was received. The drought was broken at this point by a fall of 1.45 inches over 2 days, followed by 2 light falls in May (.28 inch and .45 inch) and 3.86 inches in August of that year. Subsequently the pattern of intermittent heavy rain was resumed to give the "good seasons" reported by the local residents, the relative rain events being 3.86 inches, 29-31 August 1964 : 1.85 inches, 20-21 December 1964 : 1.44 inches, 28 November 1965 : 3.00 inches, 14 February 1966 : 2.56 inches 25 April to 4 May 1966 : 1.41 inches, 26-29 June 1966. The drought therefore lasted forty months.

Discussion

Since rainfall is notoriously variable it is to be assumed for any arid or semi-arid region that periodic droughts will occur which will adversely affect vegetation. On the other hand it also tends to be generally assumed that the vegetation of arid areas is adapted to this, the plants concerned being capable of survival by prolonged dormancy. For the general run of drought periods this is no doubt true and in this particular case we may have encountered the rare drought of exceptional severity. This view is favoured by the observation that mature desert oaks 40 feet in height died, so that presumably no drought of comparable severity had occurred during their lifetime. Rainfall records have not yet extended over a sufficiently long period to throw any light on this, but it is of interest to quote the observations of D. Lindsay (1893) who in 1891 led the Elder Exploring Expedition in a crossing of the Great Victoria Desert. The explorers Giles and Forrest in their visits to this

Figure 9.—Laterite plain 60 miles west of the Warburton Range Mission with pioneer growth of flowering subshrubs and forbs following death of spinifex.

area in 1875 and 1876 had encountered good seasons with abundant feed and water, but in 1891 on crossing the West Australian border from the east, west of the Blyth Range, Lindsay's party "entered a region so dry as to lead us to the conclusion that no rain had fallen for two or three years . . . even the spinifex was dead . . . and the mulga nearly so." (loc. cit. p. 6).

Some interesting observations are also to be found in the report of the surveyor H. L. Paine who ran a traverse from Laverton to the Warburton Range in 1931 (quoted in *Cartography in Western Australia,* 1966)

> "From the Elder Creek eastward to the Barrow Range, northward to the latitude of Spring Granite and southward to the Townsend Range, an area which was examined by myself, had enjoyed a good seasonal rainfall and was carrying a great growth of herbage and wandarrie grasses. This seasonal growth is, of course, absolutely dependent on the rainfall and I am of the opinion that this area of country is subject to great irregularity in this respect, (Reference to photographs numbers 7, 8 and 9 show much dead mulga and very little regrowth—practically no scrub feed whatever). Previously this country had been examined by Mr. Frank Hann in 1903, and Mr. H. B. Talbot in 1916, and they both reported as subject to long droughts; and I must agree also."

It now seems necessary to suppose that in these dry regions, regeneration of plants is cyclic and not continuous. Instead of a steady process of recruitment by seedlings replacing individuals which have died of old age, the sort of process expected in moist forests for example, we must suppose that at certain intervals the community is more or less wiped out, regenerating when the drought is broken. Each community in this case would be what foresters call an even-aged stand. It also follows that there may be no consistency of floristic composition in succeeding cycles. If the climatic conditions for regeneration vary, as they may well do, one species may be favoured against another so that the relative numbers of those in the stand may vary. Any floristic studies made should take this into account. The same argument applies to communities which are regularly burnt, if regeneration is effected by seed rather than coppice. There is no guarantee that the floristic composition of a community has any continuity in time in these cases.

Mortality due to drought in arid regions of Australia, and cyclic regeneration, have of course been observed and reported before in Australian literature, but not quite in these same terms. Melville (1947), Everist (1949, 1960), Parkinson (1960-61) and Hall et al. (1964) have all reported that mulga regenerates copiously in years of abnormally heavy summer rain, so that mulga stands tend to consist of even-aged groups. Parkinson (ibid) also noted that "cycles of regeneration of many species of trees and shrubs appear to occur for no apparent reason." Catastrophic mortality from drought seems to have been little reported. Pook, Costin and Moore's (1966) interesting paper does not deal with a normally arid area. Everist (1949) recorded that after the drought of 1943-46 large numbers of dead mulga trees were to be seen in South-western Queensland. He investigated this in detail in 1948 and found that the drought tended to have had a thinning effect, reducing more heavily stocked stands to about 250 trees per acre : stands already at or below this figure being little affected. This is perhaps in essence what the present writer also observed in mulga, in the discussion in this paper on Figures 5 and 6 (see page 44).

In the literature there does not seem to be any suggestion of a cycle embodying both drought mortality and subsequent regeneration, only of intermittent regeneration in heavy rainfall years. This may indicate that widespread catastrophic drought mortality is a rarity, but it may also be remarked that regeneration in wet years is not likely to survive in competition with fully stocked stands (Zimmer 1944) and probably depends on some previous depletion of the plant cover for its establishment.

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